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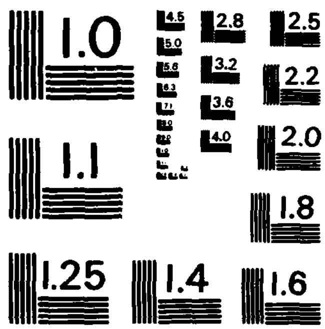

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD-A161 783

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A METHODOLOGY FOR APPLYING BAR CODE TECHNOLOGY TO AIRCRAFT MAINTENANCE UNIT SUPPORT SECTIONS

THESIS

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Captain, USAF

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AFIT/GLM/LSM/85S-79

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THESIS

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

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Paul Valovcin

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Paul Valovcin

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Abstract

This study developed a methodology that decision makers can use as an aid to determine if bar code technology should be applied in Aircraft Maintenance Unit (AMU) support sections. The literature review revealed that the Logistics Applications of Automated Marking and Reading Symbols (LOGMARS) steering group recommended that bar code technology applications be aggressively pursued across the logistics spectrum due to the success of the LOGMARS test program. Since AMU support sections perform many functions similar to those that have already benefited from this technology, a methodology was devised to aid the decision maker in identifying, and considering the tangible and intangible costs and benefits of this technology as it applies to an AMU support section. Worksheets were designed to help collect and analyze the necessary cost/benefit information so that decision makers will be able to properly assess the expected costs and benefits for a particular support section.

A METHODOLOGY FOR APPLYING BAR CODE TECHNOLOGY TO AIRCRAFT MAINTENANCE UNIT SUPPORT SECTIONS

I. Introduction

Overview

On 1 September 1981, the Joint Steering Group for Logistics Applications of Automated Marking and Reading Symbols (LOGMARS) published their final report about bar coding equipment uses in the DOD. Nine different functional areas throughout the DOD tested bar coding equipment from August 1978 to September 1981 (Joint Steering Group, 1981:1-3). As a result of the overwhelming success of this test program, the steering group recommended that "LOGMARS implementation be aggressively pursued in all logistics operations" (Joint Steering Group, 1981:1-9). These nine applications of bar coding technology saved the DOD over $113 million in addition to a series of "intangible benefits" such as "better control and accountability" (Joint Steering Group, 1981:1-7,9-2). Certainly the test program was a financial success; however, the nine areas tested were similar to areas in the civilian sector where bar coding equipment had already been used successfully. The Joint Steering Group for LOGMARS also stated in their final report "That all components consider the order of magnitude of the benefits to be derived ... when planning implementation" to ensure that a proper priority system is established (Joint

Steering Group, 1981:1-10). With budget cuts on the horizon, this new technology must be applied whenever its implementation is warranted and its efficiencies can be verified. In order to achieve this, decision makers need to know whether bar coding technology has broad applications across the logistics spectrum or whether some functions will not benefit from this technology.

Specific Problem

Aircraft maintenance unit (AMU) support sections perform inventory control and issue and receipt of items, activities similar to those evaluated in the initial LOGMARS test. Unfortunately, the economic evaluations of the LOGMARS test group were determined by the "...estimated costs and benefits based on a single transaction appropriate to each logistics function identified" (Joint Steering Group, 1981:9-1). This "single transaction" was further described as simply scanning bar coded data that normally was recorded by some manual system (Joint Steering Group, 198',.?.2). Consequently, transactions were not looked at from a total system's perspective. Also, although intangible costs and benefits were listed, their derivation was not given. Therefore, before aircraft maintenance unit support sections attempt to apply bar code technology, a methodology must be developed to identify and quantify the tangible costs and benefits, and to identify and explain the potential impacts of the intangible costs and benefits.

Literature Review

Bar Code Development. Most American consumers have experienced the impacts of bar code technology. Many grocery stores have automated their check-out procedures using optical scanning equipment to read the bar code affixed to most grocery items. The bar code seen on grocery store items is called the Universal Product Code (UPC) and has been used since 1973 (Mendez, 1983:96). Although the UPC code is perhaps the most well-known, other codes preceded it; some were patented as early as 1949 (Mendez, 1983:94). In 1960, the U.S. Patent Office issued a patent for the Rail Identification Symbol and by 1967, rail companies used this symbol to monitor the movement and contents of freight cars (Wilderman and Windham, 1978:20). In 1970, several companies worked toward their own code for grocery store applications to speed the checkout process and to improve item pricing accuracy. To coordinate their efforts, top executives from retailing, wholesaling and the grocery industry formed the National Uniform Product Council with a Symbol Technical Advisory Committee. In April 1973, this committee adopted the UPC over several alternatives and by June 1974 a grocery store in Troy, Ohio, became the first store to use this new technology (Sator, 1985:10).

Technical Description of the Bar Code. Knowing how data is encoded in bar codes helps in understanding the applications and limitations of bar coding. The following discussion serves only as a general summary of bar codes and

does not apply to each different code in use today.

The code itself is a series of bars and spaces usually of v·~ying widths (Joint Steering Group, 1981:5-1,5-2,5-3). The vertical "length" of each individual bar in the code, called the height, is meaningless in terms of data recording. Codes are usually printed as high as possible to assist in the reading of the code by a scanner. Since some scanners are fixed and the code has to be passed over the scanner before the code is read, higher bars allow for more freedom in the path used to pass the code over the reading device. Some codes are shorter because they are placed on very small items. Shorter codes such as the codes printed on packages of gum require that the code pass directly over the reading device. Since codes are different, the lengths of most codes are also different. Different codes also have unique specifications on spacing of the bars and spaces.

Reading the code depends on reflected light. As the code is passed over a fixed scanner or a portable scanner is passed over the code, the reader illuminates the code by some type of light source. The following paragraph summarizes the actual reading process:

> The light reflected back from an encoded area is sensed by the scanning device. If the light spot falls on a bar, the reflected light is minimal. If the space between the bars is illuminated by the light spot, the reflected light should be maximum. From this difference in reflected light, it is possible to tell whether the light spot illuminates a light or a space. ... The reflected light from this illumination is then sensed as a pulse width, modulated, light intensity signal wherein the received information is contained in the pattern of modulated light. This intensity modulated light is then detected by a photo transducer and converted into a voltage characterized by pulse width modulation (Joint Steering Group, 1981:5-2).

Depending on the code being scanned, the width of the bars and the spaces determine how the code information is read. The Interleaved 2 of 5 code and the 3 of 9 code both use spaces to pass information while in the regular 2 of 5 code, spaces do not contain information (Mendez, 1983:98).

Each code varies in the number of bars and spaces required to denote a character. The 3 of 9 code uses 9 elements for each character: 5 bars and 4 spaces between the bars (Venneman, 1982:3). Of these 9 bars and spaces, 3 of them are wider than the other 6; hence the name 3 of 9 (Venneman, 1982:3). The wide bars and wide spaces are of equal width. Under normal circumstances, these wide bars and spaces would be .0168 inches with a tolerance of .0017 inches while the narrow bars and spaces should be .0075 inches with a tolerance of .0017 inches (Joint Steering Group, 1981:E-10,E-11). The wide bars and spaces are determined to be a logic value of 1 and narrow spaces and bars result in logic 0. Consequently the bar code below

would be interpreted as follows:

code		
logic value	1 0 1 1 00000	00 1 1 00 1 00
character interpretation	3	9

The 3 of 9 code has codes for numbers 0 through 9, letters A through Z, and the following special characters: -, ., "space", *, $, /, +, % (Joint Steering Group, 1981:E-10,E-11). Having the capability to code these 44 characters makes the 3 of 9 code extremely versatile. Most other codes are numeric codes only and use few special characters. This alphanumeric and special character capability of the 3 of 9 code was a major reason for the DOD selecting it (Joint Steering Group, 1981:5-3,5-5).

Several other characteristics of the 3 of 9 caused this code to be the most practical code for DOD usage (Joint Steering Group, 1981:5-4,5-5). This code is bidirectional so it can be read by a scanner either right to left or left to right, and it is also of variable length. Consequently stock numbers, part numbers, or any other identifying number can be coded on an item (Joint Steering Group, 1981:5-4,5-5).

<u>Commercial</u> <u>Applications</u>. Presently, the UPC code does more than just quickly record a sales transaction. Any time

products are reduced in price or on sale, store pricing clerks enter the new price in the computer. This eliminates the need for the cashiers to know which items are on sale and at what price or which items have had price changes. Perhaps the biggest advantage though, is in the inventory control process (Mendez, 1983:96). Each time a particular item is purchased, the real-time inventory count for that item is reduced so that store managers know exactly what quantity has been sold and what quantity is still on the shelves. With this data, managers know how fast particular items in their inventory turn over. This information allows them to optimize their product line. Also, any discrepancies between the computer inventory count and the actual number of items on the shelf keep managers informed of pilferage rates. Additionally, real time inventory data provides managers with information so they can decide when to order what quantities of which items, or the system can perform these functions for the manager based on predetermined order points. Since the UPC's inception in 1973, other applications of optical scanning equipment have abounded.

The automotive industry aggressively applied this technology to manufacturing operations. Mr. Bruce A. Wray's article in the January/February 1983 issue of Bar Code News stated that the Chevrolet Motor Division of General Motors Corporation in Buffalo, New York, has used optical scanners since 1975 to sort out and route 21 different types of

axles. Similarly, Pontiac's home plant in Pontiac, Michigan, uses scanners to assist in checking for potential EPA exhaust emission violations. Mr. Wray goes on to say that an inspector with a portable bar code reader checks the various combinations of carburetors, distributors and exhaust gas recirculation valves to ensure that no illegal combinations of these three are produced. Additionally, auto bodies are produced with a bar code label attached to specify the options that will be on the final product (Wray, 1983:19).

Bar code technology has applications that 10 years ago were unimaginable. Blood banks use bar codes to identify blood types and other pertinent data to aid in processing blood or blood products for use (Wray, 1983:20). Libraries have used bar codes to speed the book sign-out process and to track overdue books (Wray, 1983:20).

Hospitals have been a fertile ground for bar code applications. In some hospitals, patients are issued 2 bar code labels that attach to their medical records when admitted. One label contains the patient's identification number while the other label contains information such as the patient's age, sex, and doctor's name (Stanley, 1983:2). Any time a patient uses a consumable item such as a bandage, the bar coded label from that item is placed in the patient's folder and when the patient is discharged, a bar code reader scans all the attached labels to determine what charges the patient incurred while being treated (Stanley,

1983:3). By moving the labels to the patient's folder, each separate hospital nursing supply station also has an accurate inventory control method for supplies and for showing consumption rates much the same as in the grocery store example (Stanley, 1983:4).

As long ago as 1979, the New York Runners Club (NYRRC) applied bar code technology to improve pre-race and post-race operations of the New York City marathon. Race administrators load entry form data into a computer which then assimilates the data and prints out a registration card for each of the 16,000 runners (Bar Code News, March/April 1983:26). When runners arrive in New York, they proceed to the registration desks and turn in their bar coded registration cards. Each card is fed into a computer which reads the card and from the information on the card produces a "data plate" for the runner to wear during the race (Bar Code News, March/April 1983:26). Along with the runner's number, this "data plate" contains a bar code of pertinent data on the runner which will be read and processed at the finish to determine runner's times (Bar Code News, March/April 1983:27,28). Manual timing was done in the past; however, this method produced many errors due to recorder fatigue, poor handwriting, or incomplete transcription of finish times (Bar Code News, March/April 1983:27). Currently, the manual system serves only as a backup to the automated bar coding system.

In Europe, the people of the Netherlands have found an

interesting application of bar code technology (van den Bergh, 1983:7,8). In the Netherlands, flowers are sold in a stock market type arrangement and sales are tracked and flowers distributed using bar code technology. Sellers of flowers separate the flowers on carts based on flower type, color, and quality. Each cart has a bar code label containing these three characteristics of the flowers. As the cart is auctioned off, this label is read and all the transactions are recorded to indicate a sale. As the cart continues on an automated distribution loop, it is routed to the designated location of the buyer where the flowers are unloaded. Over 10,000 transactions like this are completed in only a few hours (van den Bergh, 1983:7,8).

DOD Applications. Based on these and other successful applications of bar code technology in the private sector, the Department of Defense, in 1976, felt the need to explore military applications of this technology. In September, 1976, Mr. Jack Bartley, Office of the Assistant Secretary of Defense, Manpower, Reserve Affairs, and Logistics, (OASD(MRA&L)) headed the joint steering group that would chart a course of action for the Defense Department for the Logistics Applications of Automated Marking and Reading Symbols (LOGMARS) (Gould, 1982:16). The steering group's major objectives were to establish a standard symbology useable by all DOD activities and DOD suppliers and to establish certain procedures for employing this standard symbology (Gould, 1982:16)

After initial testing, the LOGMARS Senior Advisory Group (SAG) recommended that the Three-of-Nine (3 of 9, Code 39) bar code be used as the standard for the DOD. Mr. Robert B. Pirie, Jr., Assistant Secretary of Defense for Manpower, Reserve Affairs, and Logistics, approved the use of this code on 9 October 1980 and "encouraged all DOD components to proceed with the development and implementation of logistics applications of automated marking and reading technology" (Joint Steering Group, 1981:5-5).

Testing the 3-of-9 code was divided into three areas; laboratory testing, symbol marking testing, and functional area testing (Joint Steering Group, 1981:6-1). The following table typifies the positive results of the testing program on productivity (Joint Steering Group, 1981:6-22).

Test	Percent of Productivity Increase
Ammunition Inventory	500.0%
Retail Receiving	400.0%
Wholesale Receiving	222.0%

These increases in productivity can be attributed to reduced processing time for data entry into the data storage system using bar code scanning as opposed to a previous manual data entry system.

Based on these positive results, the Joint Steering Group's final report stated "Any application where faster, more accurate, data entry into an automated system will

result in increased operational effectiveness and increased material readiness is a candidate for use of automated marking and reading systems" (Joint Steering Group, 1981:5-7).

<u>Problem Background</u>. Within the Tactical Air Forces (TAF), one area apparently in need of "increased operational effectiveness" is the aircraft maintenance unit (AMU) support section. In the Tactical Air Forces, support sections maintain and control the tools, special equipment, and test equipment used to repair aircraft. Although each support section is organized differently and has different specific responsibilities that are a function of the major command, the mission design series (MDS) assigned, and local deputy commander for maintenance policy, each section still has the requirement to control its assets. Evidence indicates that support sections have recently done a less-than-adequate job of controlling their equipment.

A sample of management effectiveness inspection (MEI) final reports from Tactical Air Command, (TAC), Pacific Air Forces, (PACAF) and Alaskan Air Command (AAC) contains numerous write-ups for ineffective tool control programs. The following findings taken from MEI reports illustrate the magnitude of the problem:

Finding 053. The maintenance supervisor did not ensure tool room semiannual inventories were accomplished. (Repeat) (MEI 21TFW, 1984:33)

Finding 055. The maintenance supervisor did not ensure

basic support section programs were sound. (MEI 21TFW, 1984:34)

(DA022) The support section supervisor did not ensure the composite tool kit (CTK) program was properly managed. (MEI 474TFW, 1984:DA7)

(DA002) The AMUSS NCOIC did not ensure the CTK program was properly managed. Repeat deficiency, HQ TAC MEI, March 1982. (MEI 67TRW, 1984:DA3)

(DA14) The AGS Support Branch NCOIC did not establish equipment accountability. (MEI 347TFW, 1983:DA5)

These findings and the numerous other ones addressing tool control in support sections included some common examples to support the findings. One recurring problem was tools missing from the support section but not signed out by anyone. In other cases, semiannual and end-of-shift inventories were inadequate or were not performed.

Commercial Tool Rooms. Many commercial organizations maintain tool rooms similar to Air Force tool rooms. To support manufacturing and production operations, Todd Pacific Shipyards of Seattle, Washington, issues over 15,000 different types of tools to its 3,000 employees regularly (INTERMEC, 1984: No 6). Todd recently converted their manual tool check-in/check-out system to an automated system using bar code technology. The savings from this automated system were estimated at over $600,000 annually (Computerworld, 14 May 1984:61). Also, Todd estimated that over 16,000 production hours would be saved as a result of quicker tool check-in/check-out, less time for inventories, and less time for lost and broken tool reporting (Caple,

1982).

Todd uses an Automated Tool Inventory Control and Tracking System (ATICS) specifically designed for Todd by Data Enterprises of the Northwest, Inc. This system can provide the user with 21 different reports ranging from a simple Tool Inventory Report which tells which tools are currently in use to a more complex Suggested Tool Replenishment Report which monitors actual tool levels (Data Enterprises).

Although ATICS was a specially designed bar code system for Todd Shipyards, preliminary results indicate that Todd has experienced substantial time and money savings because of the improved operating efficiency (Harding, 1984:59,60)

Scope

This research report will develop a methodology that future researchers or decision makers can use as a framework for determining the costs and benefits of applying bar code technology to AMU support sections. Actual testing of bar code equipment was not feasible and would only have illustrated the costs and benefits for one particular support section.

Research Questions

To determine the specific costs and benefits of bar code technology to an aircraft maintenance unit support section, the following questions need to be addressed:

1. What tasks will be performed differently in an AMU

support section as a result of implementing bar code technology?

2. How can these tasks be quantified with a common unit of measurement?

3. Can the non-quantifiable tasks be evaluated?

4. How can the quantified and the non-quantified data be combined and presented to the decision maker?

II. Research Methodology

Overview

This chapter outlines the procedures that will be used to identify those variables that differ between a support section using bar code technology and one that operates using the current manual system. Additionally, this chapter also addresses how those variables will be analyzed and how this analysis will be presented to the decision maker.

Support Section Model

To establish a common frame of reference, a typical support section (tool room) will be described and the functions performed by that section will be illustrated. Day-to-day operations will be described to demonstrate the proper sequence of events and highlight various activities as they occur. This descriptive model will be based on regulation requirements, expert opinion, and the author's personal experience. Once a common reference has been established, that typical support section will be re-modeled introducing the application of bar code equipment to that section. Again, the day-to-day process will be described using this equipment.

The normal (manual) system operation will then be compared to the automated (bar coded) system operation to identify those particular activities that differ between the two systems. The differences between the manual and bar code system will then be classified. Differences between

the two systems that can be quantified will be called "tangible differences" while "intangible differences" will describe those differences that will not be measured by use of a calculable cost or benefit. If decision makers were able to completely model inputs, processes, and outputs of an AMU support section, all elements could be varied by use of the model and the results calculated. However, the methodology presented here recognizes that certain activities involve extremely complex relationships and consequently take on the characteristics of attributes known as intangibles. Intangible differences are therefore those differences that are either impractical or impossible to measure in terms of calculable costs and benefits.

Analysis of Variables

Once system differences are identified, the tangible differences will be quantified to aid in the analysis process. Each applicable tangible difference will be assigned an economic value by use of a corresponding worksheet which will collect and summarize the tangible costs or benefits associated with that particular system difference. However, since not every tangible cost or benefit is measured in dollars, each work sheet will provide an option allowing that particular cost or benefit to be converted to dollars to allow for continuity when looking at a final cost or benefit figure. For example, bar coding has proven to save manhours in certain applications;

consequently, any worksheet calculating manhour savings will have a table allowing this manhour figure to be converted to dollars. These worksheets allow anyone testing whether a bar code tool control system is feasible for a particular AMU support section to see exactly which functions performed in the support section need to be measured and how final tangible cost and benefit figures will be derived.

Intangible costs and benefits will be treated differently. Recent cost/benefit analysis literature suggests that to attempt to quantify intangible factors only serves to simplify a complex problem that should not be simplified. Mr. R.J. Radford in his book titled Modern Managerial Decision Making says that "this simplification may involve a considerable distortion of the decision situation" (Radford, 1981:17).

Consequently, this report will not attempt to integrate the intangible costs an benefits with the tangible costs and benefits to arrive at a final, comprehensive dollar amount to be used as the sole determinant as to whether a bar code tool control system should be implemented. Rather, the decision maker will have to analyze a list of factors which will be affected as a result of changing the tool control system. Some of these factors will have very real costs associated with them while other factors should serve to remind the decision maker that a purely economic decision is not appropriate.

III. Analysis

Overview

The purpose of this chapter is to devise a method to calculate the costs and benefits that would accrue to an AMU as a result of implementing bar code technology in the support section. Costs and benefits will be categorized as either tangible or intangible. Tangible costs and benefits such as manhours spent or saved, or dollars spent or saved, are measurable while intangible costs and benefits are reflected in things such as "improved inventory control and accountability."

Before a method for calculating tangible costs and benefits can be devised, these costs and benefits must be identified. Consequently, the first section of this chapter describes the duties and requirements of the support section directly related to tool and equipment control. Next, a step-by-step description will be presented explaining the tool and equipment issue/turn-in process. This explanation will describe this process using AF Forms 1297, Temporary Issue Receipt, (subsequently referred to as hand receipts) to establish accountability for tools and equipment. Units have the option of using these hand receipts, chits, or any other locally devised method as long as the integrity of a tool control system can be maintained.

This will be followed by a description of this same tool room using bar code technology applications. Again,

the issue and turn-in processes will be explained. The differences in the two systems will be identified and then classified as either tangible differences or intangible differences depending on whether or not the costs or benefits associated with the difference can be measured. Finally, any other differences between the manual and bar code system not directly related to the tool and equipment issue and turn-in process will be identified and classified.

Following this identification and classification process, the tangible differences will be listed individually followed by an explanation on how to calculate the final cost or benefit. Since intangible differences do not have a direct cost or benefit, they will be listed separately; however, they should be considered with the tangible costs and benefits when determining whether or not to implement a bar code system in a support section. Although these intangible differences will not have a specific cost associated with them, the decision maker will have to assign a relative value rating of each difference so as to indicate how important each intangible difference is to the unit.

Generic Tool Room

The basic responsibilities of support sections in the TAF are described in MCR 66-5. In an aircraft generation squadron (AGS), the maintenance supervisor has responsibility for tool room or support section operations

(MCR 66-5, para. 2-12r(2)). The maintenance supervisor has been tasked to ensure a "... well-arranged tool room to provide the required tool support" is available to AGS workcenters, or in this case AMU's (MCR 66-5, para. 2-12r(2)). Additionally, tool control is the most important responsibility of the tool room. Quantities of tools and equipment shall be sufficient to meet mission requirements but not so abundant as to be wasteful. Special tools may be displayed on shadow boards or stored in any other well-arranged fashion. Additionally, each item in the tool room must have a location/identification designator and both the tool and the tool's storage location are marked with that designator (MCR 66-5 para. 2-12r(2)).

To enhance accountability, the maintenance supervisor is tasked with setting up a tool issue suspense system (MCR 66-5 para 2-12r(2)(b)). After each shift, tool room personnel ensure all tools and equipment have been turned in or are still signed out for a valid reason.

Similarly, every 6 months or when tool room supervisors are changed, a thorough inventory is performed to ensure that each and every item controlled by the tool room is accounted for (MCR 66-5 para. 2-12r(2)(c)). Also, any time tools are lost or identified as missing, local and MAJCOM directives identify the process which must be initiated when tools and equipment can not be recovered.

Tool Room Assets

The terms "tools" and "equipment" have been used repeatedly to this point to describe the assets controlled by a tool room. These assets vary depending on the type and number of aircraft supported; however, the following list illustrates the types of tools and equipment typically found in a support section:

-Tool Boxes (106)
 --maxi-kits
 --mini-kits
-Test, Measurement and Diagnostic Equipment (TMDE)
-Technical Orders (TO's) (1300)
-Special Equipment
 --air hoses/adapters (15)
 --flashlights (58)
 --ear defenders (50)
 --headsets (40)
 --communications cords (40)
 --buckets (20)
 --ground cords
 --step ladders (28)
 --shovels (20)
 --extension cords (6)
 --coveralls
-Special Tools
 --drills
 --mallets
 --torque wrenches (38)
 --breaker bars
-Consumables
 --grease
 --oil
 --hydraulic fluid
 --paint

This list is not comprehensive; however, it does represent the types of items usually found in a support section. For the reader's information, the numbers in

parentheses behind the item names represent the quantities of those items found in the 43AMU, 21TFW, Elmendorf AFB, Alaska.

Tool and Equipment Issue and Turn-In Procedures

To establish a common frame of reference, Appendix A contains three figures which show an AMU facility, an AMU support section, and the AMU's location in relation to the flightline. Figure 1 of this appendix illustrates a typical aircraft maintenance unit facility layout while Figure 2 illustrates in more detail the actual support section. As was stated earlier, this support section is a generic representation of an AMU support section, and does not structurally represent any AMU in particular.

The following steps list the series of actions necessary to complete a tool/equipment issue action from a support section. Although some of the steps listed appear trivial, they must be enumerated in order to help identify the similarities and differences between a tool issue procedure using hand receipts, and one using bar coding.

Tool Issue Using Hand Receipt

1. Technician arrives at support section service counter.
2. Technician requests tool box, TO's, bucket, headset, and communications cord.
3. While server gathers these items, technician begins filling out the hand receipt.

4. Server deposits items on counter and technician records individual identification numbers of each item on hand receipt. (Depending on MAJCOM and AMU requirements, server also may check tool box to see if all tools are in fact accounted for and server may do the actual recording of identification numbers onto the hand receipt.) (Schumacher, 1985)
5. Once hand receipt is completed, server puts hand receipt on file.
6. Technician leaves with items.

For step 3, different units require varying amounts of information on the hand receipts. Some units only require the technician's name and the list of items signed out, while other units may require the technician's name, supervisor's name, duty phone, and the list of items signed out (Schumacher, 1985).

The tool equipment turn-in steps are as follows:

Tool Turn-In Using Hand Receipt

1. Technician returns tool box, TO's, bucket, headset and communications cord to the service counter.
2. Server retrieves hand receipt from file.
3. Server ensures identification numbers on items match the identification numbers on hand receipt, and performs a visual inventory of the

tool box to insure individual item accountability.

4. Server turns hand receipt over to technician or destroys hand receipt.

5. Technician leaves service counter and server puts equipment back in proper storage location.

If the technician had brought back only a portion of the items he originally signed out, all actions would be the same except that after verifying the identification numbers on the returned items, the server would cross out these items on the hand receipt then return the receipt to the file, awaiting the return of the remainder of the items.

Based on TACMET observations, these tool issue and return procedures occur between 300-900 times per day in each AMU, depending on the MDS supported, and the flying and maintenance activities scheduled for the day (Bergeron, 1985).

Bar Coded Toolroom

Given the requirement for asset accountability, certain adjustments would have to be made to make optimum use of bar code technology. First, an individual's flightline authorization badge would have a unique code identifying that individual. The individual's name could be coded or a special identifier such as the individual's employee number could be coded. Similarly, each individual tool box or piece of equipment would also have an assigned bar code. Individual tools within boxes would not be coded because

they are not checked out individually. The unique item identification number already used on items could be coded and attached to the item. The support section could maintain a master file of each item's assigned code and each technician's assigned code. More will be said about the uses of this master file later.

Given these simple changes required by a bar coded system, the following steps list the issue process using this technology:

Tool Issue Using Barcoding

1. Technician arrives at support section service counter.
2. Technician requests tool box, TO's, bucket, headset and communications cord.
3. Server gathers these items.
4. Server scans codes on individual badge and on equipment items.
5. Technician leaves with items.

The tool/equipment turn-in steps are as follows:

Tool Turn-In Using Barcoding:

1. Technician returns tool box, TO's, bucket, headset, and communications cord to service counter.
2. Server scans codes on items to indicate return, and also performs a visual inventory of the tool

box to insure individual item accountability.

3. Technician leaves service counter and server puts equipment back in proper storage location.

Depending on the bar code system considered, the system may not require the technician's badge be scanned to return an item. Rather the server could enter the transaction as a tool turn-in and the system would automatically delete the item(s) from the technician's account since each item will be coded with a unique code.

System Differences

Comparing the hand receipt system with the bar code system step-by-step identifies the major differences in the tool issue process. This section describes those differences between a manual and a bar coded tool control system that may result in a potential tangible cost or benefit .

Tangible Difference 1: Using bar code technology, the technician saves the time it would have normally taken to fill out the hand receipt.

This difference between the two systems is irrelevant for purposes of computing a tangible cost or benefit. The time saved by not filling out the hand receipt must not be looked at in isolation. Since filling out the hand receipt occurs simultaneously with the server gathering the required tools/equipment, no appreciable time savings are evident.

Instead of filling out the hand receipt, the technician will now be idle while the server gathers the requested items. Consequently, one can eliminate this difference as a potential source of tangible benefits of a bar code system.

Another difference in the two systems occurs at the time the server brings the items to the service counter. Under the hand receipt system, the technician or the server would write the identification number of the items received on the hand receipt when the server deposits the items on the counter. Using a bar code system, the server would use that time to scan the item identification codes to complete an issue transaction. Since relatively few items are checked out by one individual at one time, one can assume that the time to write down the identification numbers approximately equals the *time* to scan these same codes; consequently, no appreciable absolute time difference can be calculated.

Tangible Difference 2: A determinable quantity of hand receipts will be saved using bar code technology.

The bar code system would reduce the need for hand receipts by the expected number of sign-out transactions per day. As was stated before, 300 to 900 total transactions occur per day per AMU. Since one-half of these transactions are tool/equipment issue transactions and the other half are turn-in transactions, approximately 150 to 450 hand receipts could be saved per AMU per day. Since the number of forms

saved can be converted to a dollar figure, this difference will be classified as a tangible difference (TD) and will be referred to as TD-2.

Tangible Difference 3: The time spent filing hand receipts and removing hand receipts from files will be eliminated using bar code equipment.

Manually filing hand receipts for tool issue and then retrieving these receipts upon return of items takes some time. Granted, for each individual transaction the server may only take 5 seconds to file a receipt and then 5 more seconds to retrieve a receipt; however, over the course of one year, the manhour savings may be significant. Consequently, this manhour saving will be classified as a tangible difference and will be referred to as TD-3.

Tangible Difference 4: The bar code system requires the purchase of bar code equipment.

Numerous manufacturers offer a variety of equipment hardware and software with a wide range of capabilities at an equally wide price range. One can be easily confused trying to compare and contrast equipment in search of the most cost effective system. Consequently, the remainder of this section focuses on some areas that need close scrutiny when determining system requirements. The actual bar code equipment cost will be referred to as TD-4. Although the following discussion briefly addresses the physical bar code equipment, Appendix J summarizes one possible method for

sizing and setting up the computer files that would be a part of the software portion of a bar code system.

Bar Code Printer. One important determination the unit must make is whether or not it needs an inherent label making capability. Supervisors must address the conditions under which the labels will be exposed. If labels are exposed to conditions which could damage them, such as snow, rain, extreme cold or heat, blowing sand, hydraulic fluid, oil, and humidity, the unit should consider obtaining a label making capability. Supervisors must also consider whether on-hand equipment and personnel will be stable over time. If equipment is constantly moved from AMU to AMU or between squadrons, and the attached codes are changed on each move, then perhaps supervisors should consider obtaining a label making capability. Conversely, if equipment is stable and remains in the AMU and personnel codes on line badges are passed from a departing person to an incoming person, then procuring preprinted labels may be appropriate.

Processing Units/Terminals. The next major item to consider is the Central Processing Unit (CPU) or terminal. Since most transactions will occur in the support section, one CPU with attached readers/scanners should meet requirements (Modern Materials Handling, January 23, 1984:43).

Bar Code Readers/Scanners. Choosing a bar code reading system is another extremely important consideration.

Although many individual choices are available, the scanning equipment is usually classified as "light pens" or "hand-held laser scanners". Light pens are less expensive ($150 - $300), when compared to laser scanners ($1400 - $1800), however, several important differences account for this price disparity (Modern Materials Handling, January 23, 1984:41). One major difference is that light pens cannot read etched or engraved codes. Since the Air Force is considering etching bar codes on aircraft parts in the future, this may be a significant drawback when considering future expansion of the bar code system (Bar Code News, November/December 1984:32). Hand-held scanners offer some other nice features which must be weighed also. These scanners can not only read laser etched codes, they can read through any glass or plastic coatings used to protect the code. Similarly, hand-held laser scanners can read labels of less than perfect quality with surprising accuracy (Modern Materials Handling, January 23, 1984:42).

Some of these light pen and hand-held scanners can be attached to portable or hand-held terminals (Modern Materials Handling, January 23, 1984:41). These hand-held terminals contain their own battery power source and have varying degrees of memory capacity (Modern Materials Handling, January 23, 1984:41). Portable hand-held terminals offer one tremendous advantage over non-portable alternatives; hand-held terminals make turnovers of equipment from shift to shift feasible on the flightline.

Tangible Difference 5: Portable bar code readers allow units to perform tool and equipment turnovers from shift to shift on the flightline.

Instead of having outgoing shift personnel bringing the tools and equipment in to the support section at the end of their shift and the oncoming shift personnel immediately signing the equipment out again, support section personnel can take the mobile bar code reader out to the flightline and walk from aircraft to aircraft exchanging responsibility for items. In this respect, flightline personnel save time because they do not have to gather their equipment, carry it inside, and then wait in line to turn it in. Similarly, oncoming personnel do not have to wait in line to sign out equipment. The manhour savings from tool and equipment turnovers on the flightline can be easily calculated and will be referred to as TD-5.

Tangible Difference 6: Personnel must label tools/equipment and personnel flightline authorization badges with bar codes when implementing a bar code tool control system.

Coded labels will have to be put on each and every item in the support section and on flightline authorization badges and this will require a quantity of manhours to perform. Therefore TD-6 will represent the added manhour cost attributable to this labeling requirement.

Tangible Difference 7: Personnel must receive training to use a bar code control system properly.

A new bar code tool control system will result in an added cost to train personnel in use of the system. Some manufacturers will include this cost to train as part of an overall system cost, but if it is not included as an overall system cost it will have to be included separately as a training cost. This cost will be referred to as TD-7.

Tangible Difference 8: Bar code equipment will have an associated periodic maintenance cost.

As with other electrical parts and components, this equipment will require periodic maintenance (both scheduled and unscheduled.) As with the previously addressed training cost, the scheduled periodic maintenance cost may be part of an overall system cost. If not included in overall system cost, the equipment manufacturer should be able to estimate annual maintenance cost for the purchased system. TD-8 will refer to this periodic maintenance cost.

Summary of Tangible Differences. The following list summarizes the differences (TD) between a tool control system using hand receipts and one using bar code technology that result in tangible costs or benefits which can actually be calculated:

Tangible Difference 1: Using bar code technology, the technician saves the time it would have normally taken to fill out the hand receipt.

Tangible Difference 2: A determinable quantity of hand receipts will be saved using bar code technology.

Tangible Difference 3: The time spent filing hand receipts and removing hand receipts from files will be eliminated using bar code equipment.

Tangible Difference 4: The bar code system requires the purchase of bar code equipment.

Tangible Difference 5: Portable bar code readers allow units to perform tool and equipment turnovers from shift to shift on the flightline.

Tangible Difference 6: Personnel must label tools/equipment and personnel flightline authorization badges with bar codes when implementing a bar code tool control system.

Tangible Difference 7: Personnel must receive training to use a bar code control system properly.

Tangible Difference 8: Bar code equipment will have an associated periodic maintenance cost.

Calculating Tangible Differences

Appendix B contains a form which could be used to calculate TD-2. Line B1 requires the unit to record the number of hand receipts used throughout a typical maintenance week. Days 1 through 7 should correspond to 7 consecutive days of the week. If no forms are used on a particular day of the week such as in a unit which may shut down operations on a Sunday, then record a 0 for that day. Record the total number of forms used on line B1. Next multiply the figure in line B1 by 52 and record the answer on line B2. Line B2 represents the total estimated number

of forms used over the course of one year.

Line B3 requests the total number of years desired for system payback. If the unit wants to determine whether the bar code system can pay for itself over a 2 year period then put the number 2 in line B3. Another option for line B3 is to use the expected useful lifetime of the system (Economic Analysis Handbook, Second Edition: 5,6). The Economic Analysis Handbook, published by the Defense Economic Analysis Council, Handbook Committee, states that any analysis of alternatives must consider the economic life of each alternative. They define economic life as that period of time during which benefits can reasonably be expected to accrue from an alternative. Consequently, one can infer that this figure used for line B3 should not be arbitrary but in fact should represent the useful lifetime of a bar code system. For example, the system manufacturer may claim that the system should last for 7 years under normal operating conditions. In that case, record the number 7 in line B3. The figure used in line B3 will be used again for other calculations. Therefore, the unit should make every effort to determine a reasonable figure for this line.

Multiplying the annual form usage quantity from line B2 by the total estimated years in line B3 results in the total number of forms used in the time period selected. This figure goes in line B4.

Given that the most recent order of AF Forms 1297 cost $.24479 for a quantity of 250 forms, divide line B4 by 250

and record that answer in line B5 (HSG/FMCS, 1985). Next take the quantity in line B5 and multiply by $.24479, the cost of the forms. This answer in line B6 represents the total cost of the forms saved over the period of time determined in line B3. This figure will be used again in Appendix I when combining all costs and benefits.

Appendix C contains the form which is used to calculate TD-3. Line C1c simply requires an estimate, in seconds, of the time needed to file a hand receipt once it has been completed, plus, the time taken to retrieve a previously filed hand receipt once an individual arrives at the service counter.

Since line B1 (Appendix B) contains the average number of hand receipts used per week, we multiply the total filing time found in line C1c (Appendix C) by the figure in line B1 and put the result in line C2 to represent the filing time per week of all hand receipts processed that week.

Line C3 simply computes the total number of weeks specified in the time period from Appendix B. Line C3 multiplied by line C2 then results in the overall time in seconds saved and this result is placed in line C4. Line C5 computes the total manhours saved by dividing the line C4 by 3,600 seconds/hour.

At this juncture the unit has 2 options. The manhour savings computed in line C5 can be converted to a dollar figure to show the cost of manhours saved as a result of the bar code system implementation. Alternatively, this figure

can be left as is to demonstrate how many manhours could be available to perform other work in the support section such as maintaining the tools and equipment already on hand. If the unit wishes to convert manhours to dollars, then line C6 will represent this dollar figure. Line C6 will also be used again in Appendix I when combining all costs and benefits. The hourly wage rates used in this appendix and the appendices to follow, were taken from Chapter 33 of AFR 177-101, dated 1 February 1984, and represent standard rates for military personnel services.

Additionally, when deciding which hourly wage rate should be used, logic dictates that the wage rate chosen should correspond to the average rank of the servers assigned to the support section. Again, a certain amount of judgement must be used when deciding which rate to use for this calculation. Obviously, if the support section supervisor is an E-6 and he is the only E-6 assigned while the rest of the support section personnel are E-3's or E-4's, then the unit should use a wage rate that falls somewhere between the E-3 and E-4 rates.

Appendix D contains the form used to calculate the cost of the bar code equipment. Calculation of total system cost is not difficult. If a manufacturer quotes a total system cost without breaking down component costs, then simply skip this form and include the total system cost directly in Appendix I when tabulating overall costs or benefits. Otherwise use this form as a guide to determining overall

bar code system costs. This form only specifies costs for the CPU, scanners, printer, and the software development costs; however, due to the differences in each manufacturers systems, these four categories of items may not be all-inclusive. As a result, use line D6, miscellaneous expenses, to include any costs peculiar to a particular manufacturer's system such as costs for interface cables or extra user's manuals.

The next major savings resulting from the use of bar code equipment is in the area of tool and equipment turnover from shift to shift on the flightline. Appendix E contains the form used to aid in calculating this manhour savings. Before estimating this savings, look at Figure 3, Appendix A, for the relationship between the AMU location and the parking plan. Assume the AMU has 24 aircraft which are either parked in rows I, J, or K on spots 1 through 8, or the aircraft are in the AMU hangar or the phase hangar. The aircraft can be located at numerous other places but these three locations are generally the primary aircraft locations where AMU personnel will work on the aircraft. For example, an AMU aircraft may be in another hangar to be used for weapons load training; however, maintenance personnel will generally not be with the aircraft performing maintenance while that aircraft is used for this training.

Assume also that the AMU works a two-shift operation; day shift and swing shift. Under certain circumstances, day shift personnel, at the end of their shift, will pack up all

their tools and equipment and proceed to the support section to turn in the items they signed out. Swing shift personnel will then sign out the equipment brought in by day shift personnel and go right back out to an aircraft on the flightline. In other cases, swing shift personnel may actually sign out equipment before day shift turns their equipment in and then go out to their work location and relieve their day shift counterparts. Day shift technicians will then pack up their equipment and come in to the support section and turn the equipment in. This second scenario requires the support section to maintain almost enough tools and equipment to support two complete shifts as opposed to one set of equipment that is constantly turned over from shift to shift (Williams, 1985).

In still other cases, combinations of methods are used to enhance equipment turnovers between shifts. Shift changes may be staggered so that a few swing shift personnel come in early, sign out their equipment and then relieve their dayshift counterparts (Schumacher, 1985). These relieved day shift personnel then turn in their equipment which the next group of swing shift personnel sign out. Finally, other units have their swing shift personnel relieve their day shift personnel and the outgoing day shift personnel go through the support section and report who now has responsibility for their equipment. This last method may be more common than is desirable; however,its ease of use allows for the erosion of the concept of asset control,

the crux of the "tool control system." In any case, the summary of inspection findings in chapter 1 reflects that a lack of asset control is definitely a problem, regardless of the underlying cause.

Given these diverse methods of performing tool and equipment turnover between shifts, Appendix E attempts to determine the manhour savings by performing this turnover on the flightline or in the hangers using bar code equipment as opposed to a turnover which takes place in the support section using hand receipts.

Lines E1, E3, E4, E5, and E6 break down each individual task in the tool turn-in process. In essence, this is the total productive time (in manhours) generated as a result of not having tool box and equipment turnovers on the flightline. Determining the time estimates in seconds for each of these tasks requires that one actually perform the tasks while being timed. Line E3 requests the approximate time in seconds to walk or drive back in to the support section because in some locations walking back in to the support section is not feasible and expediters use their vehicles to move personnel from place to place. Line E8 converts the total number of seconds to manhours.

Line E9 is perhaps the most important estimate on this Appendix. As was stated previously, units use many options for turning tools and equipment over between shifts. However, only those turnovers that take place in the support section should be counted. If the tools and equipment do

not leave the flightline or work location during shift changes but rather personnel swap responsibility for these items without taking these items in to the support section, then these turnovers do not count when determining the proper figure to use in line E9. On the other hand, if an individual, at the end of his shift, returns all the items he signed out at the beginning of his shift and his replacement for the next shift signs out those same or similar items, then these transactions will count for estimating line E9. Under all circumstances, a certain amount of judgement is needed when making an estimation for line E9.

As with Appendix C, this manhour figure in line E9 can be looked at in isolation as a potential source of manhours available for more productive work by virtue of making tool box turnovers on the flightline a matter of practice. Alternatively, this figure can be converted in line E10 to a dollar figure which will be used again in Appendix I when figuring overall system costs and benefits.

Appendix F provides a guide for determining the overall time and cost to label all items controlled by the support section. This estimate should be somewhat longer than the time it would normally take to do a 6-month inventory due to the requirement to label all items after verifying proper accountability. The overall estimate should be placed in line F1. Line F2 simply converts this manhour estimate into a dollar figure as was done previously in Appendices C and

E.

The next costs to determine are the initial training costs associated with implementing a bar code tool control system. Appendix G collects these costs. If the system manufacturer offers training as part of the overall system cost, then line G1 should be disregarded. However, some manufacturers may charge a fee to provide an initial training program and if so, this fee should be recorded on line G1. Regardless of how the cost of initial training is recorded, manhours will be expended by key personnel in order to become proficient in use of the bar code system. These training hours should be recorded on line G2 and once again, can be left as manhours or converted to a dollar figure on line G3. Line G4 simply totals the training cost which will be used for future calculations in Appendix I. Recurring training costs are assumed to be equal regardless of the system used.

The final tangible cost requiring estimation is the periodic maintenance cost. Since the aircraft maintenance unit will not have any historical data with which to forecast future periodic maintenance costs, the unit will have to ask the manufacturer for an estimate of these costs. This estimate should be placed in line I8 of Appendix I.

Combining Tangible Differences

Appendix I contains the worksheet for determining overall costs or benefits as a result of the tangible

differences between a tool room using hand receipts and one using bar code technology. This form requires that the individual combine figures already derived in previous appendices by adding all the expected benefits and then subtracting all the expected costs. Line I10, if positive, indicates an overall benefit to the organization based on the quantifiable system differences. Conversely, a negative answer in this line indicates that the system may not be cost effective pending the decision maker's judgement of the expected intangible costs and benefits.

Intangible Differences

While the previous discussion focused on those system differences that could be measured in terms of dollars, time, or manhours, the following discussion addresses those differences that are difficult to measure or quantify such as "improved inventory control and accountability" and "user resistance to an automated tool sign-out system."

The first half of this section is devoted to identifying potential intangible differences and discussing how these differences will be manifested in the support section's day-to-day activities. The remainder of the section will then discuss how to integrate these intangible system differences with the tangible differences so that a decision can be made to either buy the equipment or retain the manual tool control system.

Intangible Difference 1: The bar code system will supply the support section with usage rates for all items controlled by the support section from information collected during tool issue and turn-in, thus eliminating the need to maintain any manual files or listings.

Currently, AMU personnel decide how many tool boxes and individual pieces of equipment are needed to support maintenance activities except for items listed on the unit's Customer Account/Custody Receipt Listing. Their decision as to the correct quantities needed are effected by such things as the availability of funds to purchase tools and equipment, mobility commitments, size of the support section, and number of personnel in the AMU by AFSC. Maintenance personnel within the AMU make decisions as to which items are needed and in what quantities based on those factors listed and on any other factors which may be appropriate. Once inventory levels are set and items are used on a day-to-day basis, the AMU does not generally know how often each item is signed out. Consequently, the AMU would be unable to determine if they have too many or too few of certain items unless they maintain some type of historical documentation.

One could speculate that shortages are generally not a problem with items that the AMU has the authority and the money to purchase. Rather, since AMU's tend to plan for the worst case, the support sections may have a larger inventory than is optimal.

A bar code system with a sufficient memory capability, would be able to produce a summary of usage rates by item. Over the course of one year's time, the AMU could use such a summary to develop an idea of the quantities of items needed to support maintenance activities.

A bar code system could track peak demand for like items. For example, coding could be set up such that the system could track how many times and for how long like items were signed out. If the unit has 20 APG mini-kits and on occasion, all 20 kits are signed out, the unit might consider increasing the number of APG mini-kits. Conversely, if the unit has 20 tank hanging kits but only 10 are ever signed out at once, then the unit could reduce the number of these kits. Perhaps in the final analysis, a unit may find they have exactly the proper quantities of items on hand, but without information on usage rates they would not have been able to determine optimal levels of items with certainty.

Similarly, the unit would also be able to determine more accurately the usage rates for consumable items. Many items such as batteries and Armorall (used to clean radomes on some aircraft) are considered highly pilferable items. By having consumption data on these items, a supervisor can readily see if these items are being used properly. Although a bar code system will not directly improve the control of these items, it may increase awareness that a control problem exists with these items.

Items such as engine oil, paint, grease, and hydraulic fluid can also be tracked for consumption data to establish a baseline on-hand quantity.

Intangible Difference 2: Supervisors have a real-time, extremely accurate listing of which technician signed out what items.

Any time someone has the need to determine who signed an item or which item(s) a particular person has signed out, the bar code system can provide that information much faster than a manual system.

If a supervisor has a need to know, quickly, who has signed out a particular item, he can go to the support section and query the system. The system could immediately respond with the individual's name or technician employee number. As was stated previously, a master file of bar codes assigned to employees and to items controlled by the support section would be on hand. These master codes would be used to query the system to see who signed out which items or to see what items a particular technician signed out. To do this with a manual system would require someone to physically search the hand receipt file looking for the item in question on each hand receipt.

Similarly, shift change inventories could be performed more accurately. A supervisor with a portable scanner could walk through the support section scanning the code for each item missing from the section. The scanner would then

respond by indicating if the item is or is not legitimately signed out. If signed out properly, the scanner could respond with the appropriate technician employee number or name, depending on how the line badges are coded.

This accurate and timely information provided by the system has another benefit. A supervisor can more easily check whether technicians under his supervision have the tools and equipment necessary to perform a particular job. If for some reason a supervisor has duties which keep him from getting out on the flightline for a particular period of time, he can use this automated tool control system to check and see who has signed out what equipment. For example, this would allow him to see if his subordinates signed out the necessary technical orders required for a particular job. Of course signing out the correct equipment does not guarantee the proper use of that equipment, but this can be a valuable supplemental source of information.

Bar code data also eliminates errors that are characteristic of manual data storage and retrieval systems. Typically, problems with hand receipts occur when personnel accidently write down the wrong information, information is misread, hand receipts are misfiled or the information on hand receipts is illegible. Regardless of the cause of error, manual data storage and retrieval systems are subject to error. To put the accuracy of the bar code system in perspective, manual key punch data usually has 10,000 errors per 3 million key punch strikes while a bar code system has

proven to be extremely accurate by only having 1 error per 3 million entries (80 Micro, November 1983:98). Some users report accuracy rates as high as 1 error in 20 million entries but of course many factors affect such a high accuracy rate (Isaacson, 1984:94).

Intangible Difference 3: The bar code tool control system can generate an overdue tool report from information collected during tool issue and turn-in, thus eliminating the need to maintain any manual files or listings.

Having a bar code system with an internal clock allows the automated tool control system to identify which tools have been signed out for an extended period of time.

The system could be designed to automatically generate a report whenever tools and equipment exceed a predetermined sign out time. Along the same lines, a flight chief could go into the support section and query the system to find out which individuals in his flight on a particular shift still had tools signed out.

This clocking mechanism is especially useful when personnel change shifts. Personnel in the support section, over time, become accustomed to seeing a particular person on a certain shift; and as personnel change shifts, the support section may not be looking for overdue items.

Intangible Difference 4: Personnel in the AMU may be resistant to a bar code tool control system.

Resistance to an automated tool control system may come from two causes. Tool room personnel may be opposed to any automated system. They may see a change to an automated system as an indicator that AMU supervision is not satisfied with the quality of their work. Since the automated system has the potential to free more time for support section personnel, they may be forced to do jobs they were previously not required to perform. Also the support section supervisor may see the automated system as an attempt to cut the quantity of personnel assigned to that section.

Intangible Difference 5: A bar coded system can be designed so that tools and equipment overdue calibration can not be checked out.

Depending on the storage capacity of the system, calibration due dates for all items requiring calibration could be maintained by the automated system. With this information, the system could perform two distinct functions. First it could supply a report of up-coming calibration requirements. For example, the AMU could request a calibration due listing on each Friday of all items due calibration the following week. Secondly, the automated system could be programmed so that it would not accept the code of an item that is overdue calibration. Realistically each unit should have some method of controlling items requiring calibration; however, this

capability of the bar code system could serve as a supplement or as a replacement to the established system and provide another method of control.

Intangible Difference 6: The bar code tool control system can keep track of tool failure data by item or by technician using the item.

Sometimes it may prove valuable to know which tools break frequently and also which people have a tendency to break tools. Once the correct number of tool boxes and special tools are firmly established, tool break rates will allow support section personnel to have a better idea of the quantities of spares they should have on hand. Under current systems, broken tools are not always tracked. Some MAJCOM's require that a broken tool log be established, however, many times AMU's only record the tools which are actually missing from the tool box or support section when there are no spares to fill in. In this situation, when a unit has spares, it replaces a broken tool with a new spare and no entry of a broken tool is ever entered in the broken tool log.

Similarly, by having an automated method to track broken tools, supervisors will know who frequently breaks tools. Of course, an individual who has broken a considerable amount of tools over a period of time may not be negligent or purposely destructive. Rather, the types of maintenance that person performs may make his tools more

susceptible to breakage. As was stated earlier, this data, which is retrievable from an automated system, should merely supplement other information sources in the AMU.

Intangible difference 7: The bar code tool control system is dependent upon a reliable electrical power source.

Although this difference is obvious, the significance of the difference can not be overstressed. In times of power failure, a unit will have to resort to a manual tool control system. Depending on the location of the unit, power outages may be rare events that occur for a few hours at a time.

Other units may face more frequent outages. Units overseas and in foreign countries may receive their power from a local company and this power supply may not be reliable. Some bases, such a Clark AB, Republic of Philippines, generally have power outages on some part of the base every day (Byron, 1985). Of course this situation may change but it should weigh in any decision to automate a tool room.

Intangible Difference 8: Building up pallets for mobility could be improved with bar coding.

Many factors affect which items are actually loaded on pallets for mobility responses. Sometimes an odd number of aircraft are deployed and so pallet loading does not meet predetermined load requirements. Also, sometimes certain equipment is not available to be loaded. Items may be

broken, in PMEL, or already deployed and so may not be available according to the predetermined plan. As a result, the pallet weight, cube, and inventory data will change. Using a bar code system to collect and then list the pallet contents provides a way to eliminate the hand transcribed listing which is subject to error. The bar code system could record each item on the pallet and when the pallet is loaded, produce a master inventory listing that displays the weight and cube data.

Summary of Intangible Differences. The following list summarizes the differences between a tool control system using hand receipts and one using bar code technology that would be difficult for the unit to measure or if measurable, would not be easily quantifiable for someone not specifically trained in cost/benefit analysis:

Intangible Difference 1: The bar code system will supply the support section with usage rates for all items controlled by the support section from information collected during tool issue and turn-in, thus eliminating the need to maintain any manual files or listings.

Intangible Difference 2: Supervisors have a real-time, extremely accurate listing of which technician signed out what items.

Intangible Difference 3: The bar code tool control system can generate an overdue tool report from information collected during tool issue and turn-in, thus eliminating

the need to maintain any manual files or listings.

Intangible Difference 4: Personnel in the AMU may be resistant to a bar code tool control system.

Intangible Difference 5: A bar coded system can be designed so that tools and equipment overdue calibration can not be checked out.

Intangible Difference 6: The bar code tool control system can keep track of tool failure data by item or by technician using the item.

Intangible difference 7: The bar code tool control system is dependent upon a reliable electrical power source.

Intangible Difference 8: Building up pallets for mobility could be improved with bar coding.

Valuing Intangible Differences

Unlike the tangible differences, the intangible differences are somewhat hard to directly quantify, especially for the decision maker who may not be trained in the complex area of cost/benefit analysis. Therefore, valuing intangible differences will be done in a somewhat unique fashion. Valuing intangible differences will be a process in which the decision maker must determine a subjective level of importance for each intangible difference.

Appendix H lists all the intangible differences as they appear in this text. At the top of the appendix is a scale representing different levels of importance from "not

important" through "somewhat important" to "extremely important." All that is required of the decision maker is that he review each difference and rank each difference as to its relative importance or value to the organization. For example if the unit has absolutely no need for an overdue tool report, the decision maker should rate intangible difference 3 as 0. Conversely, if the unit believes they need more equipment and wants to support their contention using historical usage rates, then intangible difference 1 may be valued as 10.

The significant aspect of filling out this worksheet is that it causes the decision maker to consider how important each intangible difference is to the unit. Also, no correlation can be made between the value assigned to any one individual difference and to the value assigned to any other individual difference. Combining the relative importance of the specific differences with the analysis of each intangible difference allows the decision maker to weigh the overall positive and negative impacts of these intangible differences. For example, a unit may place a high value on a reliable electrical power source but if that power source is not reliable then a bar code tool control system would probably not be a wise choice.

Combining Tangible and Intangible Benefits

Much literature has been written on cost/benefit analysis. Unfortunately most of the published literature

addresses cost/benefit analysis in terms of overall profit. However, the DOD is a nonprofit organization with hard to measure outputs such as national defense or deterrence. Consequently, trying to place a monetary value on expected intangible costs and benefits is not appropriate. Any calculations would involve estimates that would be extremely complex to determine and would vary based on individual preferences regarding the value of information. The interrelation of these intangible variables further complicates any attempt to quantify them. For these reasons, any quantitative value assigned would provide less valuable assistance in the decision making process than consideration of these differences as intangibles.

All cost benefit analysis experts agree however, that intangibles can and should weigh in decisions with economic implications (Oxenfeldt, 1979:51). More recently, individuals have come to stress the fact that "the experience and intuition of those involved in a decision situation becomes a major factor in the choice between alternative courses of action and between outcomes" (Radford, 1981:19). Even the Economic Analysis Handbook published by the DOD addresses the importance of the decision maker's judgement when it says, "The adequacy of the cost analysis must be judged by the decision maker within the context of the problem" (Economic Analysis Handbook, Second Edition:7). Decision making under absolute certainty as to the costs and expected benefits occurs

rarely and often times, decision makers make assumptions to simplify a very complex situation when the situation should not be simplified (Radford, 1981:90).

Given this guidance, the decision maker must make a judgement as to how the intangible costs and benefits associated with implementing bar code technology in a support section should weigh when combined with the easily calculable tangible costs and benefits.

Therefore, in order to adequately consider intangibles, the decision maker must have access to an objective analysis of each of the intangible differences. The decision maker must weigh these intangible considerations in light of his or her own expertise, experience, and the tangible difference data as summarized in the format of Appendix I. Additionally, the intangibles listed in this paper may not be complete; therefore, a unit should make every effort to consider all the situation specific effects of implementing the bar code technology.

IV. Conclusions and Recommendations

Conclusions

This research effort has led to several conclusions:

1. The cost/benefit analysis of the initial LOGMARS test performed under the guidance of the Joint Steering Group for LOGMARS was not as comprehensive as it could have been. As was stated in Chapter I, the benefits of bar code applications throughout the DOD were based on the cumulative savings attributable to entering data into various systems using bar coded data entry verses manual data entry for each transaction. Because in most cases, reading a bar code label will be faster than manual entry of the same data, one would expect such research to predict cost and manpower savings. However, the act of inputting data into a data control system must not be observed in isolation. The entire data control system must be analyzed from a broader system's perspective when determining costs and benefits of any control system utilizing bar code technology.
2. An overall methodology was found for identifying the differences in a tool control system using AF Forms 1297, and one using bar code technology. Furthermore, general guidelines were provided for calculating actual costs or benefits for those differences that will result in actual costs or savings in terms of manhours or dollars.
3. Basic cost/benefit analysis techniques usable by an untrained decision maker do not allow the decision maker to

quantify the intangible differences identified. Consequently, the evaluation of these intangible differences is a purely subjective evaluation with no overall economic end result. Furthermore, in order to decide whether a bar code tool control system should replace the manual control system, the decision maker must use his own experience and judgement when combining the subjective intangible costs and benefits with the objective tangible cost and benefits.

Recommendations for Future Research

1. An attempt should be made to implement bar code technology in an AMU support section at some representative location in the Tactical Air Forces regardless of how the cost/benefit figures turn out. Possibly, some tangible and intangible costs and benefits would arise that were not identifiable in this research project.
2. A thorough location design analysis should be performed on a selected AMU support section to determine the optimum storage locations for items controlled by the support section. Given the significant number of transactions per AMU per day, a support section that is not organized to facilitate the movement of items in and out of the section could benefit from an in-depth location analysis.
3. Another potential area for research concerns the types and quantity of information that is potentially retrievable from a bar code tool control system. Todd Shipbuilding, a company that uses bar coding in their tool rooms, has a

system that can provide up to 21 different reports to tool room managers. Although one could become saturated with information, an effort should be made to determine what information would help AMU personnel and a bar code system could be developed given those requirements.

4. Although MCR 66-5 gives units the latitude to use any type of tool control system that meets the criteria of effective tool control and accountability, support sections could benefit from research which identifies the advantages and disadvantages of the control system using chits and the one using hand receipts, the two most common methods of control. For example, using the chit system, end of shift inventories only require that a chit be in the place of any item missing from the support section. This is an advantage over the hand receipt system since every hand receipt must be reconciled against the items missing.

5. The Air Force could also benefit from the development of "generic" computer software that would be usable in any tool and equipment control application. By performing the tedious task of developing the computer code and logic that would form the basis of a bar code tool control system, the Air Force could save a significant amount of money by not having to develop software for each potential application of bar coding in tool rooms. If the developed software had applications across many functional areas that have a tool control requirement such as aircraft maintenance, missile maintenance, vehicle maintenance, and various civil

engineering functions, economies of scale could be realized. Also, economies of scale could be realized then in the purchasing of hardware required for an automated tool control system.

Appendix A: AMU Figures

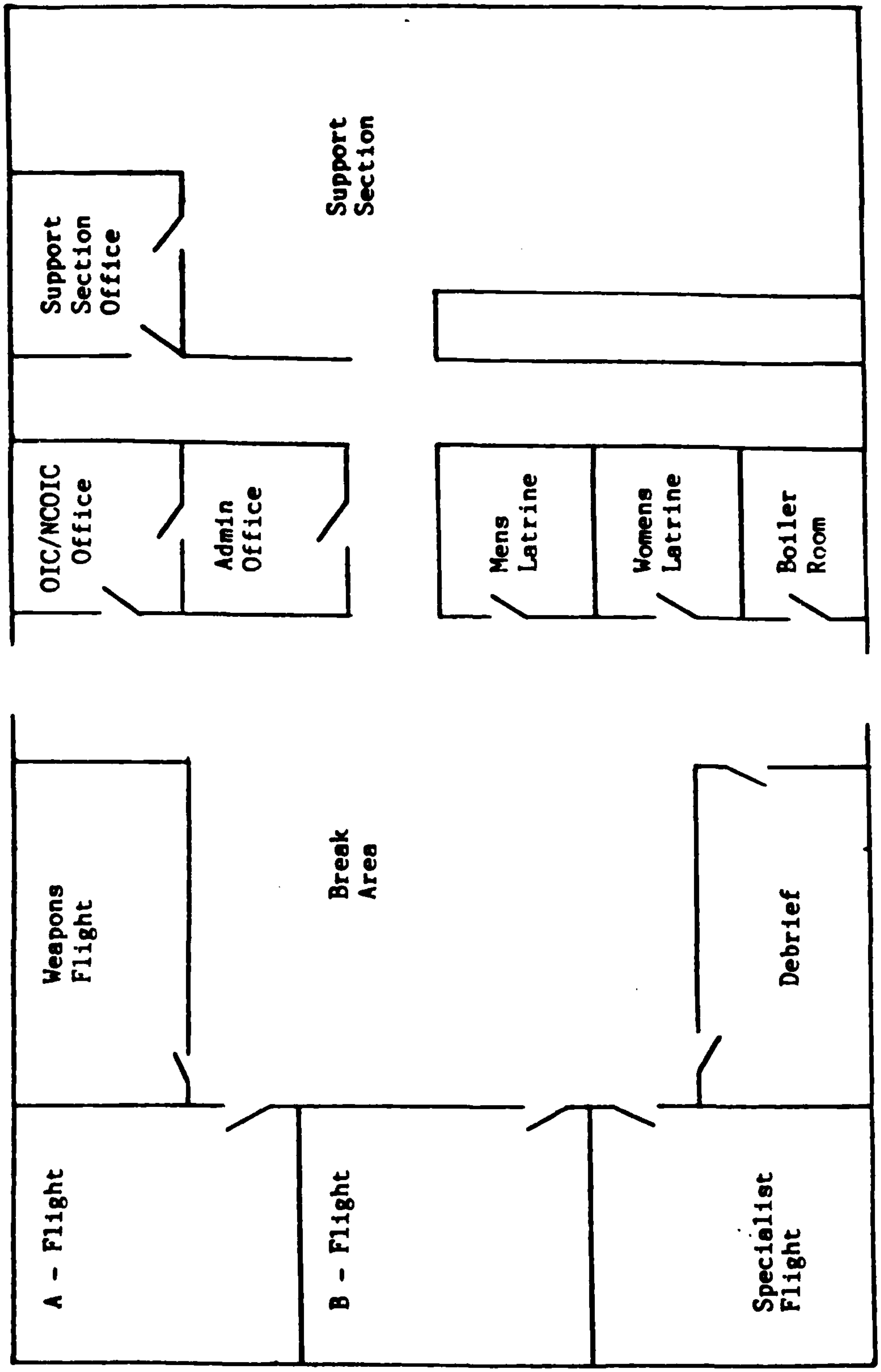

Figure 1: AMU Facility

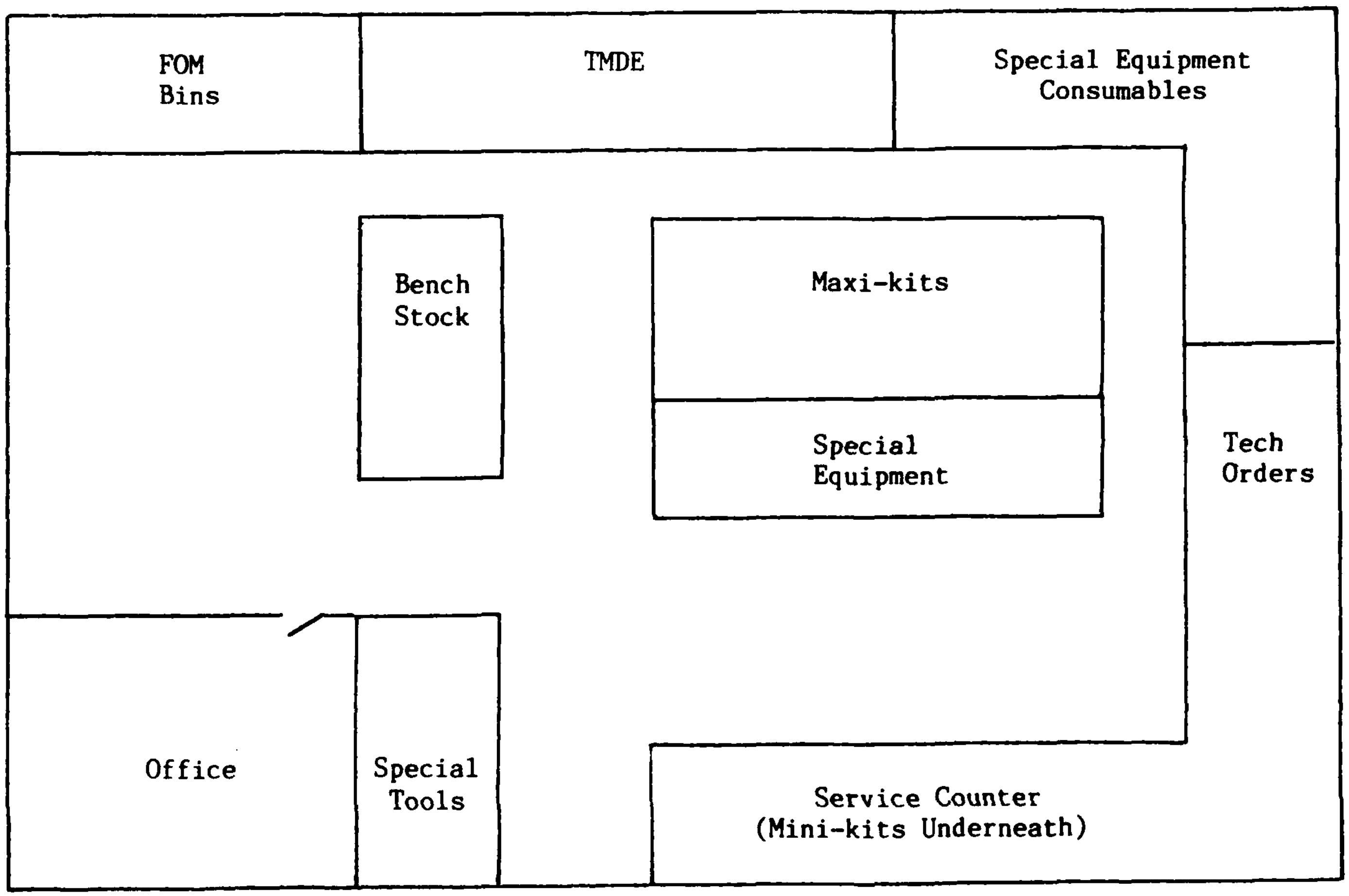

Figure 2: Support Section

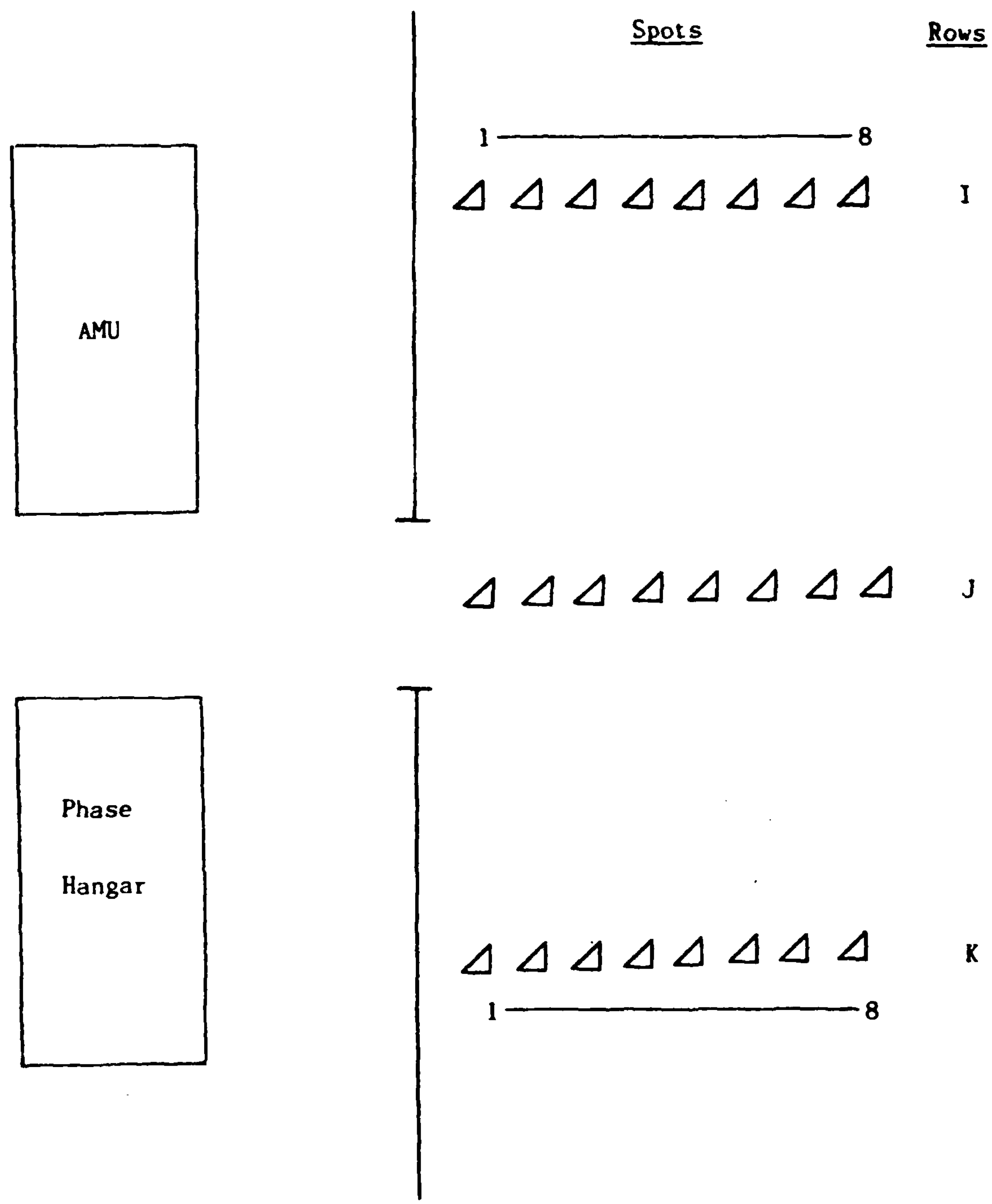

Figure 3: Flightline

Appendix B: Calculating TD-2

B1. Number of AF Form 1297's used:

Day 1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7

Total B1. ______

B2. Multiply Line B1 by 52. B2. ______

B3. Determine number years desired for system payback period. B3. ______

B4. Multiply line B3 by line B2. Line B4 represents the total # of forms used over the time period determined in years in line B3. B4. ______

B5. Since AF Forms 1297 cost $.24479 per 250 forms, divide line B4 by 250. B5. ______

B6. Multiply Line B5 by $.24479. Line B6 represents the savings attributable to not using AF Forms 1297 with a bar code system. B6. ______

Appendix C: Calculating TD-3

C1. Time to file and remove from file hand receipts.

C1a. Estimate the time to file hand receipts (in seconds). C1a.______

C1b. Estimate the time to remove from file hand receipts (in seconds). C1b.______

C1c. Total (C1a + C1b). C1c.______

C2. Multiply line C1c by line B1 of Appendix B to get filing time per week for all hand receipts processed per week. C2. ______

C3. Multiply 52 by the number in Line B3 of Appendix B. C3. ______

C4. Multiply Line C3 by line C2 to get total time in seconds saved by not filing or removing from file the hand receipts. C4. ______

C5. Divide line C4 by 3,600 to get the total number of manhours saved during the time period specified (in years) from Appendix B, line B3. C5. ______

C6.

Rank	Hourly Wage Rate (FY84 dollars)
E-9	17.37
E-8	14.79
E-7	12.81
E-6	11.08
E-5	9.40
E-4	8.07
E-3	6.91
E-2	6.22
E-1	5.62

Multiply hourly wage rate representing the typical server's rank by the figure in Line C5 to get the potential dollar savings attributed to the manhours savings based on bar code equipment.

C6. ______

Appendix D: Calculating TD-4

Bar Code Equipment Cost

D1. Central Processing Unit cost. D1. ______

D2. Lightpens or hand held scanners.

D2a. Number of scanners required ___.

D2b. Cost per scanner ___.

D2c. Multiply D2a by D2b ___.

D2d. Cost of any portable readers with memory ___.

D2e. Add D2c and D2d for total cost of readers. D2. ______

D3. Bar Code Printer Cost. D3. ______

D4. Cost of Blank Labels. D4. ______

D5. Software Development Costs. D5. ______

D6. Miscellaneous expenses such as for interface cables etc. Periodic maintenance costs may be included here. D6. ______

D7. Add lines D1 through D6 for total system cost. D7. ______

Appendix E: Calculating TD-5

E1. Gathering up equipment takes approximately ___ seconds, prior to walking into the support section. E1. ______

E2. Estimate the average distance to walk/drive from the flightline to the support section service counter. E2. _____ft.

E3. Actually walking/driving this approximated distance carrying a representative amount of tools/equipment takes approximately ___ seconds. E3. ______

E4. The turning in of equipment by a day shift individual and the signing out again of this relatively same equipment takes approximately ___ seconds. E4. ______

E5. Walking/driving back out to the approximated average distance takes approximately ___ seconds E5. ______

E6. Opening up the tool box and setting up equipment takes approximately ___ seconds. E6. ______

E7. Adding Lines E1,E3,E4,E5, and E6 indicates the time spent turning over equipment from shift to shift. E7. ______

E8. Divide Line E7 by 3,600 to determine the

number of manhours used in tool and equipment turnover for each turnover action. E8. ______

E9. Multiply Line E8 by the estimated number of shift to shift turnovers performed in the support section per day per AMU. E9. ______

E10.

Rank	Hourly Wage Rate (FY84 dollars)
E-9	17.37
E-8	14.79
E-7	12.81
E-6	11.08
E-5	9.40
E-4	8.07
E-3	6.91
E-2	6.22
E-1	5.62

E10. ______

Appendix F: Calculating TD-6

F1. Estimate the time in manhours needed to perform a complete tool room inventory and to label all items with a bar coded label. F1. ______

F2.

Rank	Hourly Wage Rate (FY84 dollars)
E-9	17.37
E-8	14.79
E-7	12.81
E-6	11.08
E-5	9.40
E-4	8.07
E-3	6.91
E-2	6.22
E-1	5.62

F2. ______

Appendix G: Calculating TD-7

If initial system training cost are part of overall system cost as given by the manufacturer, then do not fill in line G1.

G1. Estimated cost of initial training as supplied by the bar code equipment vendor. G1. ______

G2. Estimated manhours lost due to training. G2. ______

G3. Cost of manhours lost to training.

Rank	Hourly Wage Rate (FY84 dollars)
E-9	17.37
E-8	14.79
E-7	12.81
E-6	11.08
E-5	9.40
E-4	8.07
E-3	6.91
E-2	6.22
E-1	5.62

G3. ______

G4. Add lines G1 and G3 for total costs. G4. ______

Appendix H: Valuing Intangible Differences

not important					somewhat important					very important
0	1	2	3	4	5	6	7	8	9	10

Intangible Differences	Value
Intangible Difference 1: The bar code system will supply the support section with usage rates for all items controlled by the support section from information collected during tool issue and turn-in, thus eliminating the need to maintain any manual files or listings.	ID1. ______
Intangible Difference 2: Supervisors have a real-time, extremely accurate listing of which technician signed out what item.	ID2. ______
Intangible Difference 3: The bar code tool control system can generate an overdue tool report from information collected during tool issue and turn-in, thus eliminating the need to maintain any manual files or listings.	ID3. ______
Intangible Difference 4: Personnel in the AMU may be resistant to a bar code tool control system.	ID4. ______

Intangible Difference 5: A bar coded system can be manipulated so that tools and equipment overdue calibration can not be checked out. ID5. ______

Intangible Difference 6: The bar code tool control system can keep track of tool failure data by item or by technician using the item. ID6. ______

Intangible difference 7: The bar code tool control system is dependent upon a reliable electrical power source. ID7. ______

Intangible Difference 8: Building up pallets for mobility could be improved with bar coding. ID8. ______

Appendix I: Combining Tangible Differences

This appendix computes an overall cost or benefit as a result of the tangible differences between a tool room using hand receipts and one using bar coding.

Computing Benefits:

I1. Copy the figure from line B1 (Appendix B) here. This figure represents dollars saved on hand receipts. I1. ______

I2. Copy the figure from line C6 (Appendix C) here. This figure represents the dollar value of manhours saved from not filing hand receipts. I2. ______

I3. Copy the figure from line E10 (Appendix E) here. This figure represents the dollar value of manhours saved by performing shift turnovers on the flightline. I3. ______

I4. Add lines I1, I2, and I3 to find total benefits. I4. ______

Computing Costs:

I5. If a manufacturer quotes a total system cost without breaking down component costs, then put that figure here. Otherwise, copy the figure from line D7 (Appendix D) here. I5. ______

I6. Copy the figure from line F2 (Appendix F) here. This figure represents the cost to inventory and label all items with a bar code label. I6. ______

I7. Copy the figure from line G4 (Appendix G) here. This represents the cost of training personnel to use bar code equipment. I7. ______

I8. If the periodic maintenance costs are not included in the total system cost, then include those costs here. Multiply the expected annual maintenance cost by the expected lifetime of the equipment as given in line B3 and put the result here. I8. ______

I9. Add lines I5, I6, I7, and I8 to find the total cost. I9. ______

I10. Subtract line I9 from line I4. If the answer is positive, this represents the expected benefit attributable to the tangible system differences. If negative, this represents the expected cost attributable to these same differences. I10. ______

Appendix J: Bar Code Equipment Considerations

As stated earlier, numerous manufacturers offer a variety of bar code equipment hardware and software with a wide range of capabilities and an equally wide price range. Personnel at the wing or squadron level who choose to evaluate a bar code system may not have the experience or understanding of computer systems to judge whether a system would meet the specified requirements. Consequently, the remainder of this section is devoted to explaining the capacity requirements of a bar code tool control system. This section summarizes information provided by Captain Frank J. Murray of the Air Force Institute of Technology. Captain Murray is well qualified to address this subject as he has an MA in Computer Data Management, has seven years experience as a Functional Systems Analyst for the Air Force and is a former Adjunct Professor of Computer Science for Chapman College.

The first data base needed by a bar code tool control system is information about the people who will sign out the tools and equipment. The computer will record certain information about the people who use the support section. The file this is information will be stored in will be referred to as the "People File".

The people file would have a reserved storage space for each individual in the AMU. For our purposes, we will assume a hypothetical AMU with 300 persons assigned. The

reserved storage space for each individual in the AMU should be further subdivided so that certain information can be stored that relates to that particular person. The "number of characters of storage" shown below serve only to illustrate typical quantities of characters reserved for the listed information items. Also, the information items themselves may not represent the information the unit feels the need to store. The following list summarizes the information that will be stored under each individual in the AMU:

Information	Number of Characters of storage required
Name	27
Employee number	5
Shift designator	1
Items signed out (25 items X 8 char./item = 200 characters)	200
Total Characters	233 characters

Since 233 characters are needed per person and there are 300 people in the AMU, this file will be 233 x 300 = 69,900 characters large or require approximately 70k of memory.

Similarly, another file called "Item File" must be available. This file would be set up the same as People File except that now we are focusing on the items controlled by the support section. Just as we assumed 300 people in the AMU, we will assume there are 5000 different items controlled by the support section.

The following list summarizes the information that will be stored about each item in the AMU:

Information	Number of Characters of Storage Required
NSN	17
Item identification Number	8
Location storage number	6
employee number	5
Date/Time signed out	10
Total	46 characters

Since 46 characters are needed per item and there are 5000 items, this file will be 46 x 5000 = 230,000 characters large or require 230K of memory.

Given People File and Item File, and the appropriate bar code equipment, a unit should be able to operate on a day-to-day basis and maintain control of all equipment items while having up-to-the-minute accuracy of information.

To establish usage rates of items and to maintain some long term data requires the establishment of historical files. Consequently, a third file called "Historical Transactions" should be developed. As with the other files listed, the historical transaction file would be set up in a matrix form having the following information.

Information	Number of characters of Storage Required
Item identification	8
Employee Number	5
Date/Time Issued	10
Date/Time Turn-In	10
Total	33 characters

As was stated previously, the number of transactions per day per AMU ranges in the neighborhood of 150 to 450, consequently, the range of character space required per day for historical documentation would be 4950 to 14850. If a unit wants a 30, 60, or 90 day historical file then the following list summarizes the total storage needed for this file.

30 Day	4950 x 30 = 148500 14850 x 30 = 445500 Range 149k to 446k
60 Day	4950 x 60 = 297000 14850 x 60 = 891000 Range 297k to 891k
90 Day	4950 x 90 = 445500 14850 x 90 = 1336500 Range 446k to 1337k

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VITA

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Following his assignment in PACAF, he was assigned to the Air Force Institute of Technology where he earned a Master of Science Degree in Logistics Management. His follow on assignment is to the 57th Fighter Weapons Wing at Nellis AFB, Nevada.

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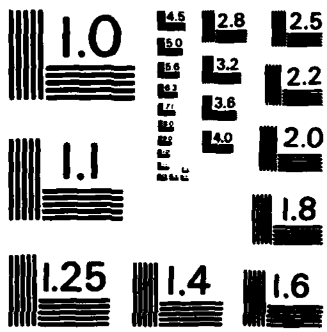

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

This study developed a methodology that decision makers can use as an aid to determine if bar code technology should be applied in Aircraft Maintenance Unit (AMU) Support Sections. The literature review revealed that the Logistics Applications of Automated Marking and Reading Symbols (LOGMARS) steering group recommended that bar code technology applications be aggressively pursued across the logistics spectrum due to the success of the LOGMARS test program. Since AMU support sections perform many functions similar to those that have already benefited from this technology, a methodology was devised to aid the decision maker in identifying and considering the tangible and intangible costs and benefits of this technology as it applies to an AMU support section. Worksheets were designed to help collect and analyze the necessary cost/benefit information so that decision makers will be able to properly assess the expected costs and benefits for a particular support section.

* U.S.Government Printing Office: 1985 — 646-047/20376

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